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PRELIMINARY TESTS OF DOUBLER BUSS QUENCH PROTECTION AND DETECTION

R.H.Flora, R.Lauckner, and R.Stiening

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INTRODUCTION

Part of the vertical dewar test program in Lab 5 and the 4-magnet string tests in B12 have been devoted to investigations of quench capacity of the Doubler dipole and quadrupole buss, and the quench loads incurred in simulations of the proposed quench protection system. Results indicate that it is more difficult to protect the buss than the magnets and a new scheme of active protection of the buss is proposed.

PROTECTION SYSTEM

This is shown in Fig. 1. When studying the buss we must also keep in mind the situation around straight sections, a possible scheme is shown in Fig. 2. Three salient parameters of this system are the sensitivity of the detection system (Itty Bitty Monitor) which has operated reliably with a resistive voltage threshold of 5 V in B12, the quench capacity of the components and the quench loads incurred. The detection threshold is liable to rise in the tunnel with longer lengths of cable. Quench capacity measurements have been made for the magnets by R.H.Flora (Fig. 3), and vertical dewar tests indicate that the collar and coil assemblies will withstand 7×10^{6} A^2s quench loads with no apparent damage.

BUSS QUENCH CAPACITY

Reference 1 explains the concepts of quench capacity and quench load. Doubler buss is made in the same manner as magnet cable except that the single strand wire is drawn down from 0.027" to 0.025". Following Reference 1, we see that this reduces the capacity by $(25/24)^4$ to 5.1×10^6 A^2s. While this value may be applied to the part of the buss embedded in the magnet coils, cooling must be considered when the buss is bathed in the single phase. An estimate of this situation has been obtained by a vertical dewar measurement. Figure 4 shows the arrangement for this test. Regular magnet cable was used for the hairpin, the inset photo shows how it was held onto a G-10 tube with glass tape and supported in the dewar with phenolic collars. We have found that the cooling environment dominates this type of measurement but chose this one rather arbitrarily.

Quenches were started by capacitor discharge into the quench resistor. With a steady current, total voltage, temperature of the hot spot and propogation velocity were measured. Results are shown in Figs. 5 and 6. Good agreement is found between the 4000 amps case and Fig. 3. Cooling is very important at low currents and the total voltages are disturbingly low.

BUSS INSIDE MAGNET

Isolated quenches in straight sections are arguably unlikely and it is not too late to substitute fully stabilized superconductor in these regions. We have also observed quenches originating inside the magnets and spreading to the buss. Figure 7 shows the arrangement of one such test made on the 4-magnet string.

Two thousand amps dc were circulating in the string when the test sequence was initiated. Figure 8 shows the ensuing quench load.

Information on a third type of quench, starting in the buss, has been obtained from a vertical dewar test. This quench was started 6" away from the point of entry into the dipole. Parameters were:

Steady Current Throughout	2000 A
Quench Load Applied	3.0×10^6 A^2s
Total Voltage Developed in Buss	2.1 V
Total Voltage Developed in Magnet	5.0V

This is another unlikely quench but the quench protection system we have been testing would only marginally have prevented damage to the buss. The quench load above added to the quench load incurred during the time to bring the current down to 5.0×10^6 A^2s which is the capacity of the buss.

RECOMMENDATIONS

Buss quenches are hard to detect and once detected must be extinguished with a small quench load because of the reduced dimensions of the buss in the magnets.

Although we have not investigated all quench situations the following recommendations are made:

1. Long isolated sections of buss should be made of fully stabilized conductor. If space permits this could be

made by paralleling four regular magnet cables leaving space between for cooling.

2. Replace the present passive protection with an active buss protection scheme. A possible candidate is shown in Fig. 9. We have no evidence that passive protection is insufficient for busses inside magnets but the active scheme has the tremendous advantage of economizing some 200 safety leads, as well as being safer. Following normal protection philosophy as soon as any irregularity is detected by the IBM, the buss protection will be activated and will bring down the current from 4000 A with a quench load of $<1\times10^6$ A^2s. Such a rapid decay induces 1 kV in the buss but this is an acceptable potential.

REFERENCE

1. R.H.Flora, M.Kuchnir, A.V.Tollestrup, Quench Development in Magnets Made With Multifilamentary NbTi Cable, Fermilab TM-686, August 17, 1976.

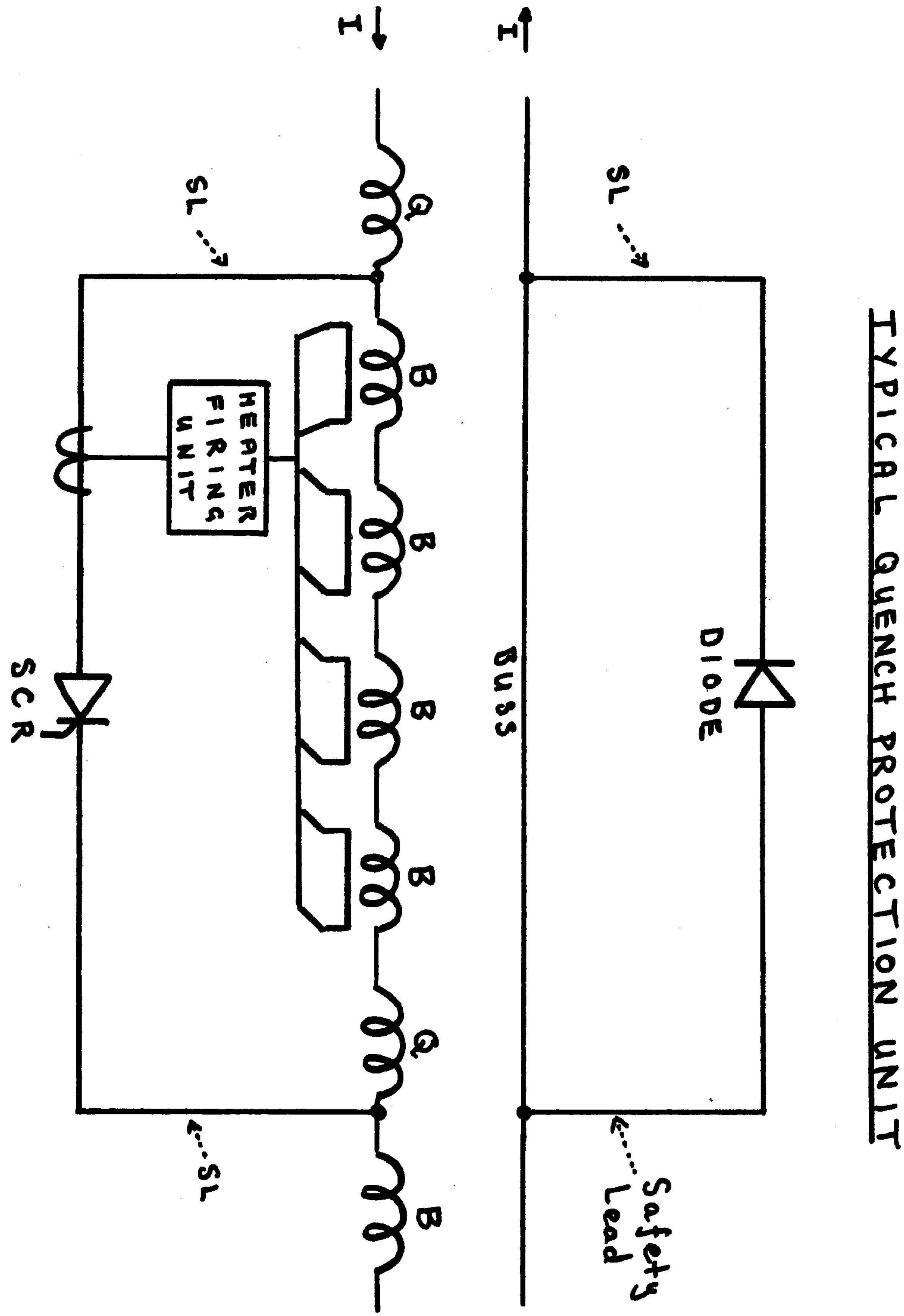

TYPICAL QUENCH PROTECTION UNIT
I
I
SL
SL
Q
B
B
B
B
Q
B
HEATER FIRING UNIT
SCR
BUSS
DIODE
SL
Safety Lead

FIGURE 1

SPECIAL PROTECTION UNIT FOR MEDIUM STRAIGHT

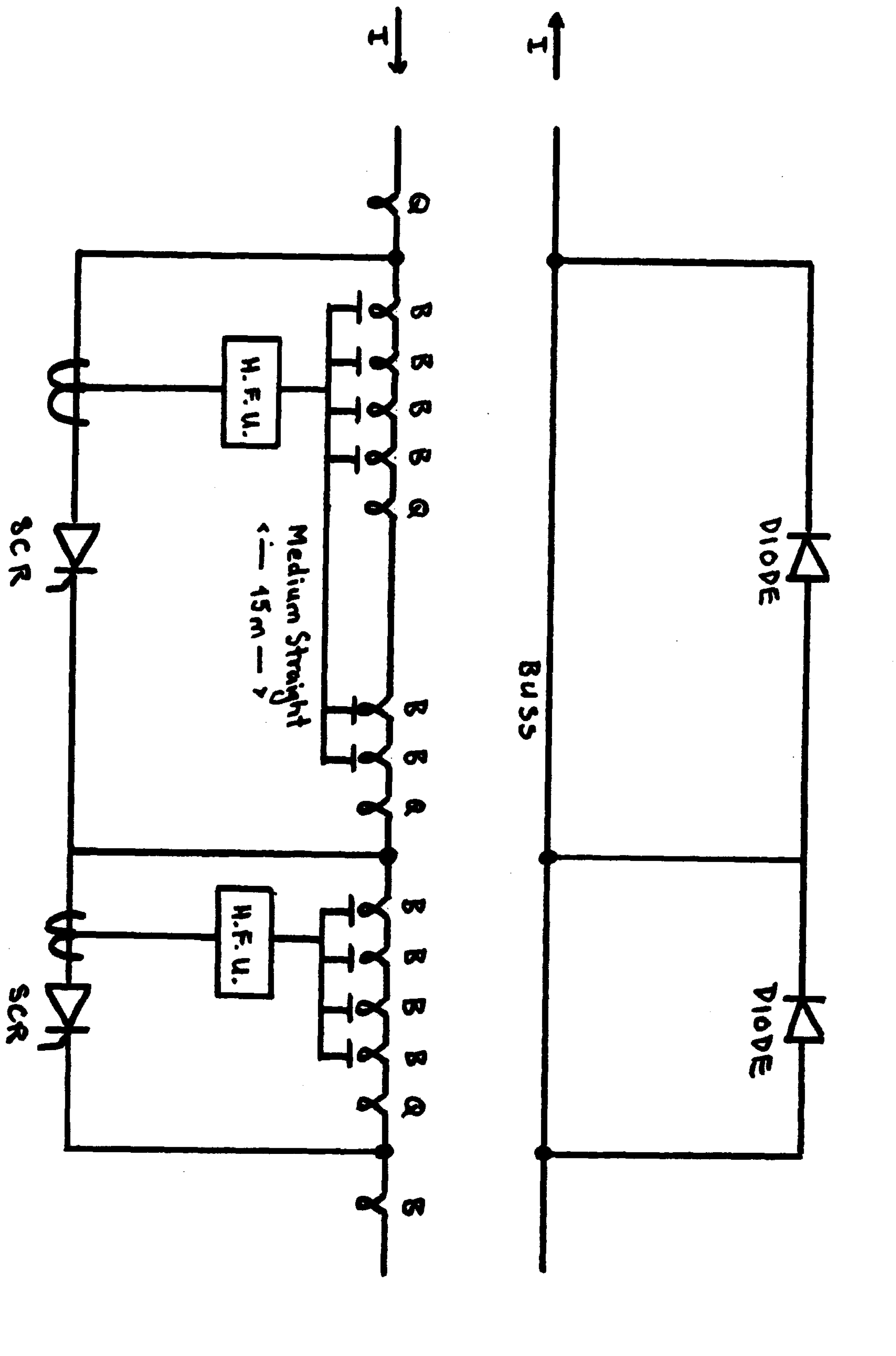


FIGURE 2

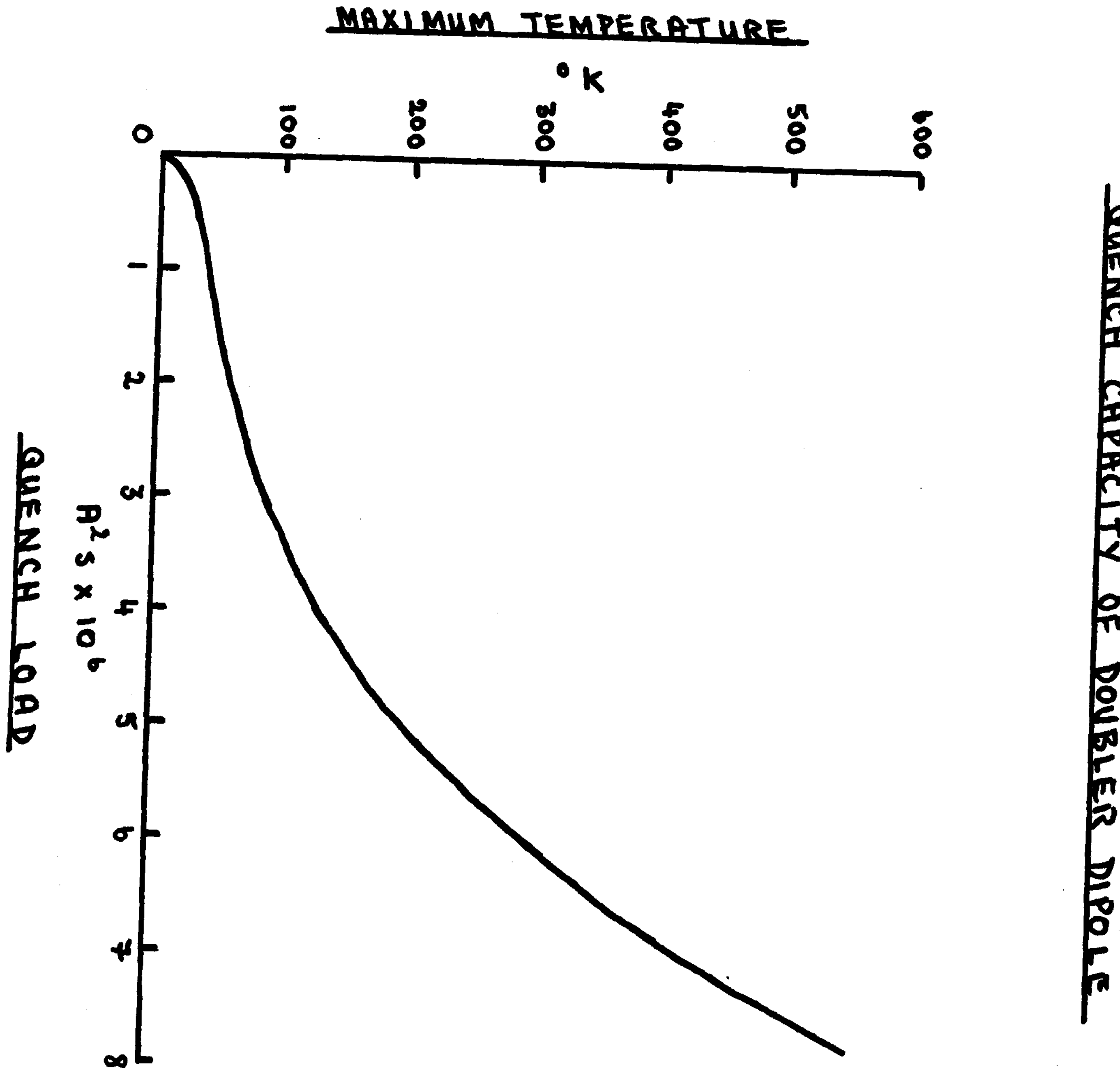
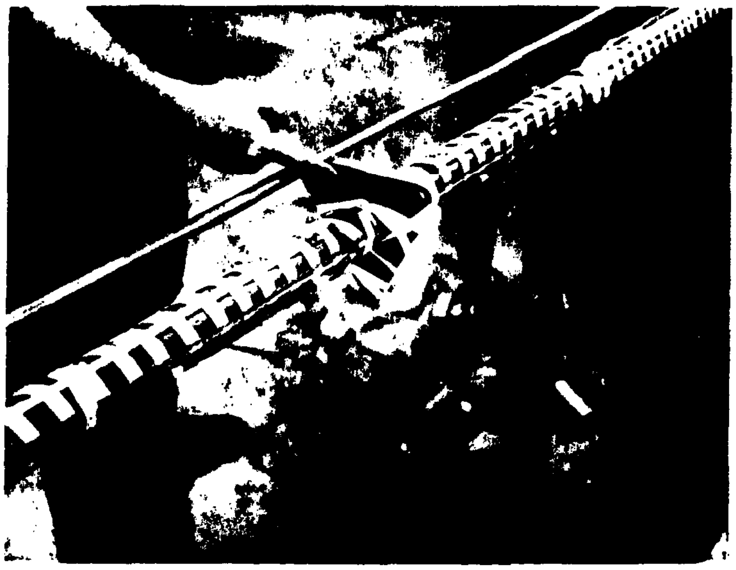
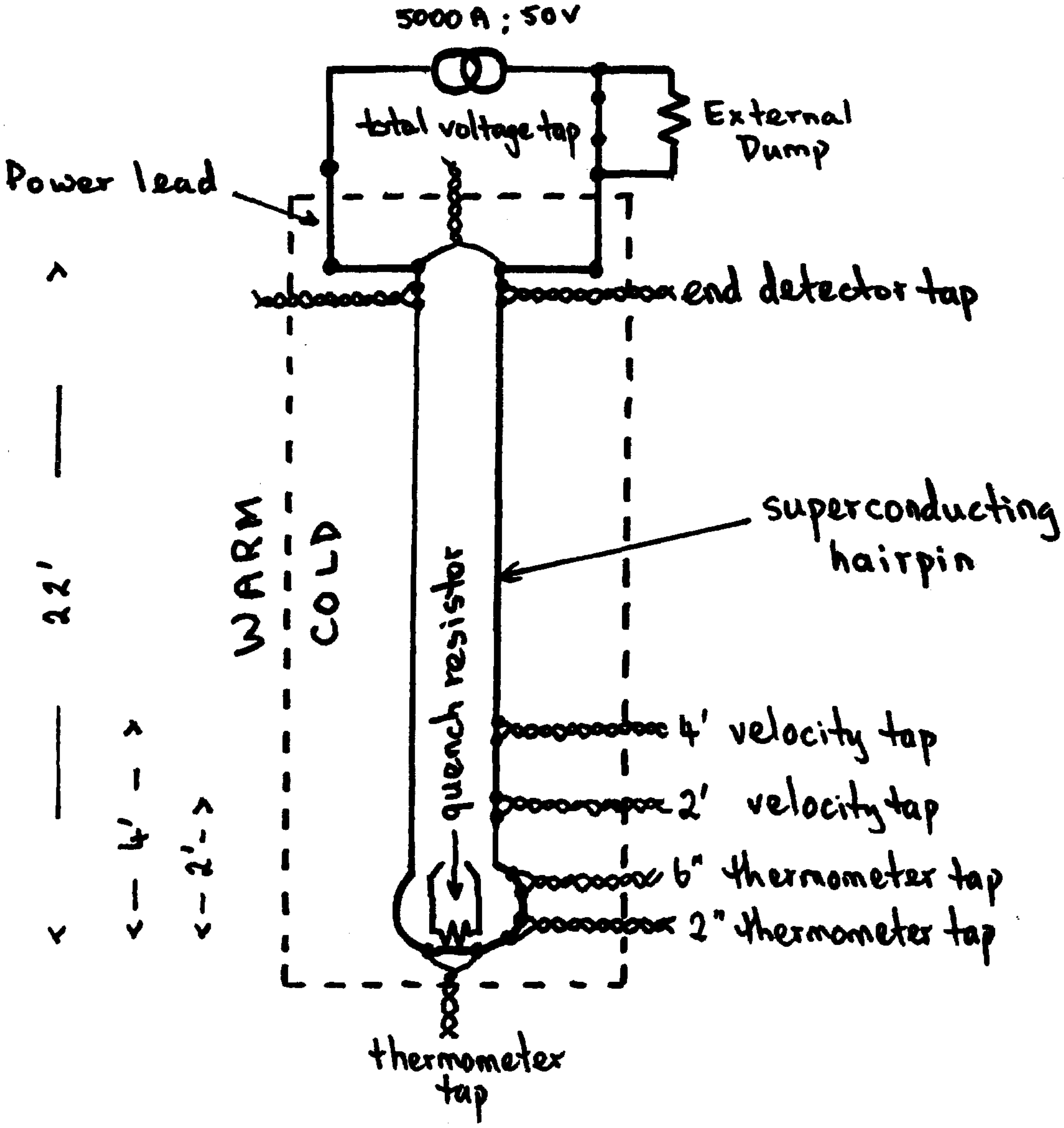

MAXIMUM TEMPERATURE
°K
0
100
200
300
400
500
600
1
2
3
4
5
6
7
8
$A^2 s \times 10^6$
QUENCH LOAD
QUENCH CAPACITY OF DOUBLER DIPOLE

FIGURE 3





QUENCH CAPACITY MEASUREMENT

FIGURE 4

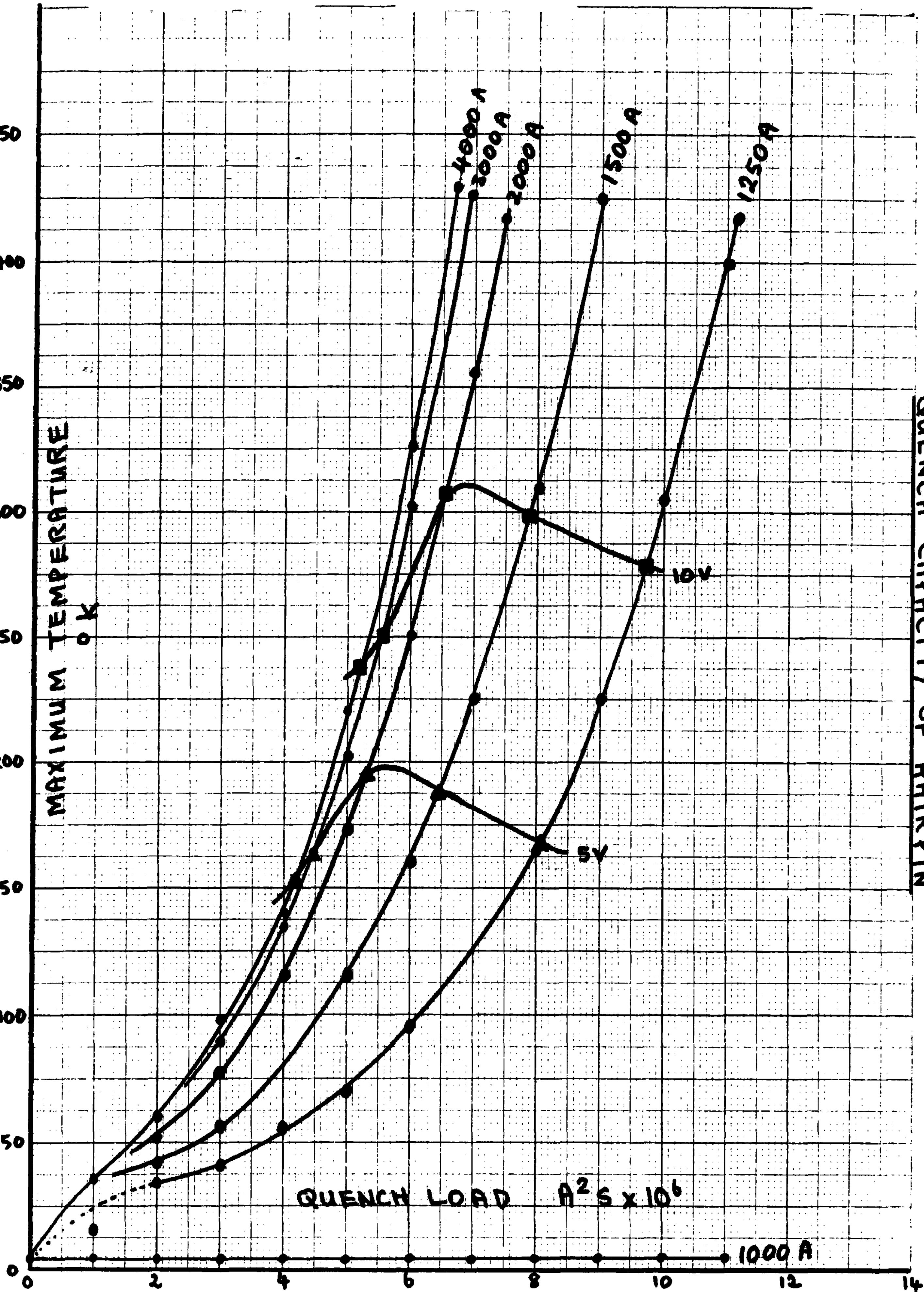

MAXIMUM TEMPERATURE
°K
QUENCH CAPACITY OF HAIRPIN
QUENCH LOAD $A^2 S \times 10^6$
4000 A
3000 A
2000 A
1500 A
1250 A
1000 A
10V
5V
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14

FIGURE 5

NORMAL ZONE PROPOGATION VELOCITY IN HAIRPIN

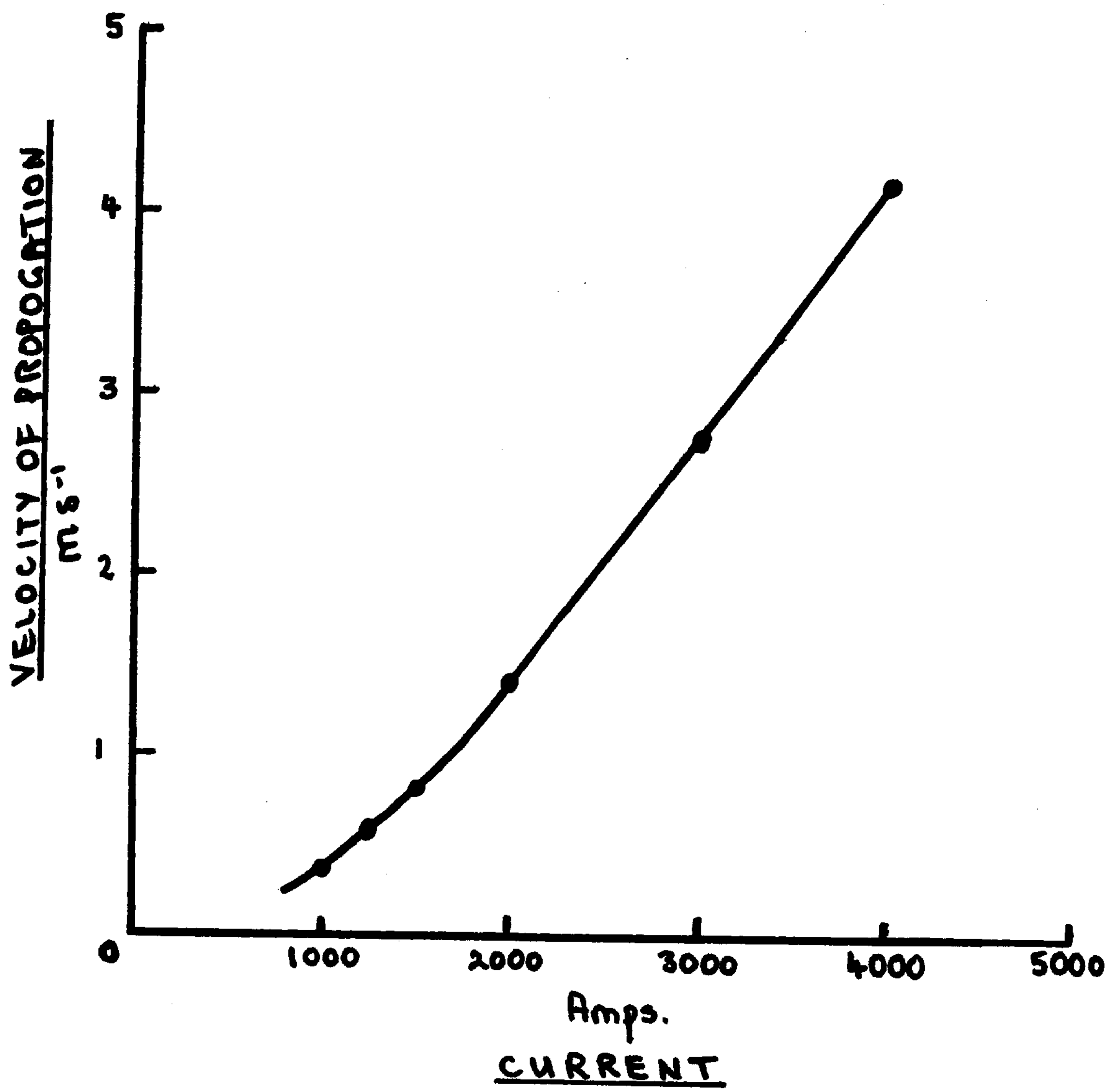


FIGURE 6

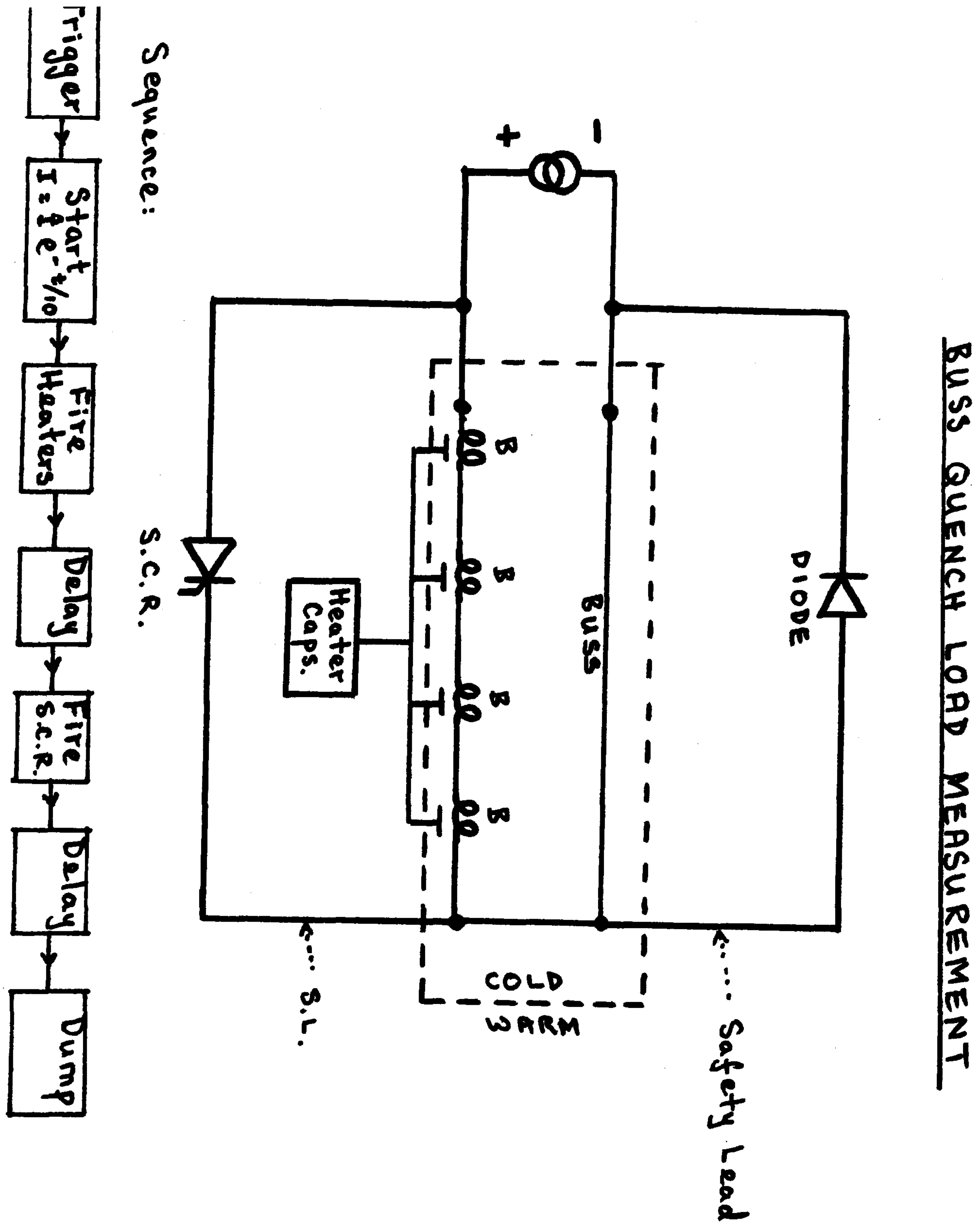

BUSS QUENCH LOAD MEASUREMENT
+
-
DIODE
BUSS
B
B
B
B
Heater Caps.
S.C.R.
COLD
WARM
S.L.
Safety Lead
Sequence:
Trigger
Start I=I e^-t/10
Fire Heaters
Delay
Fire S.C.R.
Delay
Dump

FIGURE 7

AWNING TEST 78:07:26 THIRD 2000 A QUENCH

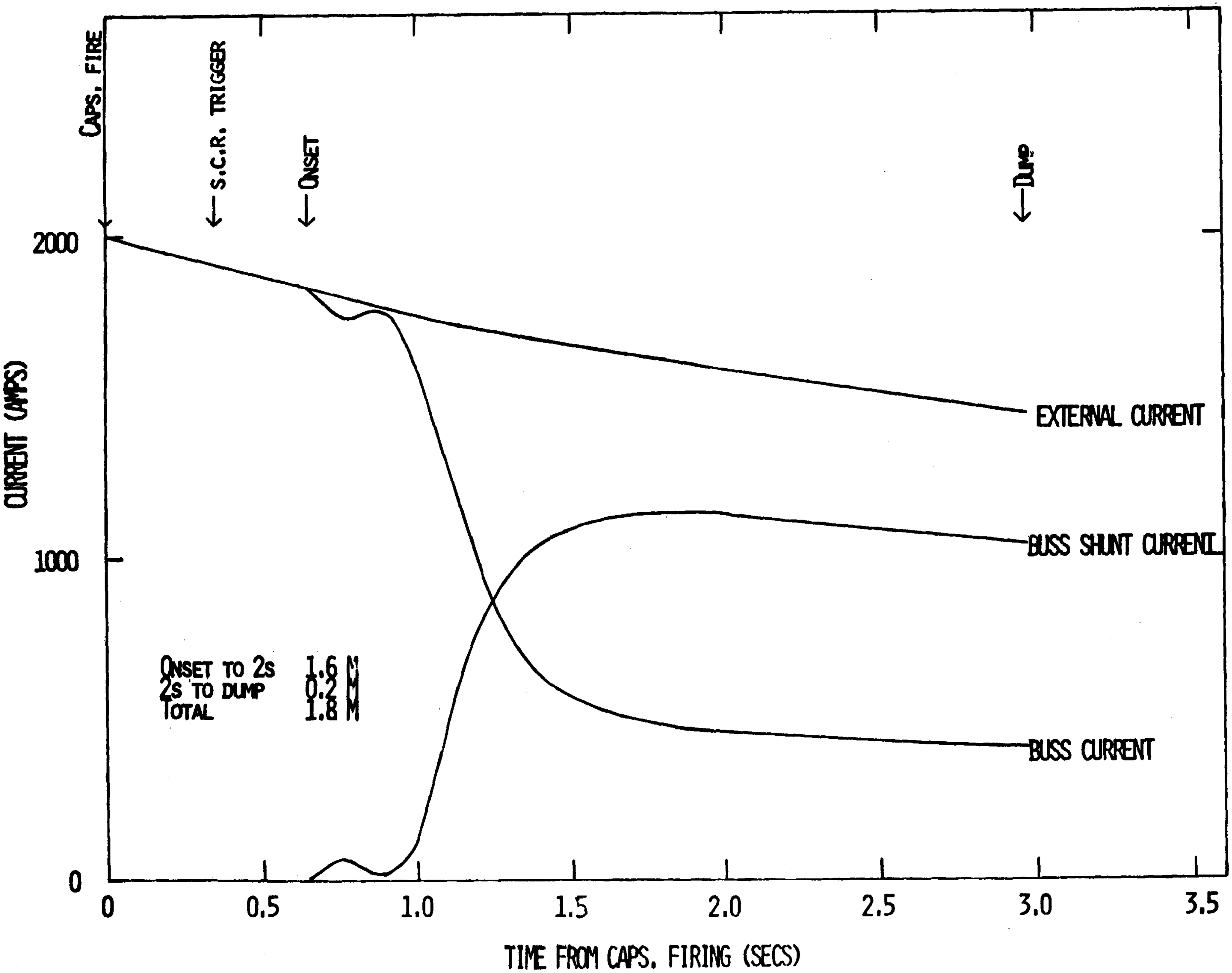


FIGURE 8

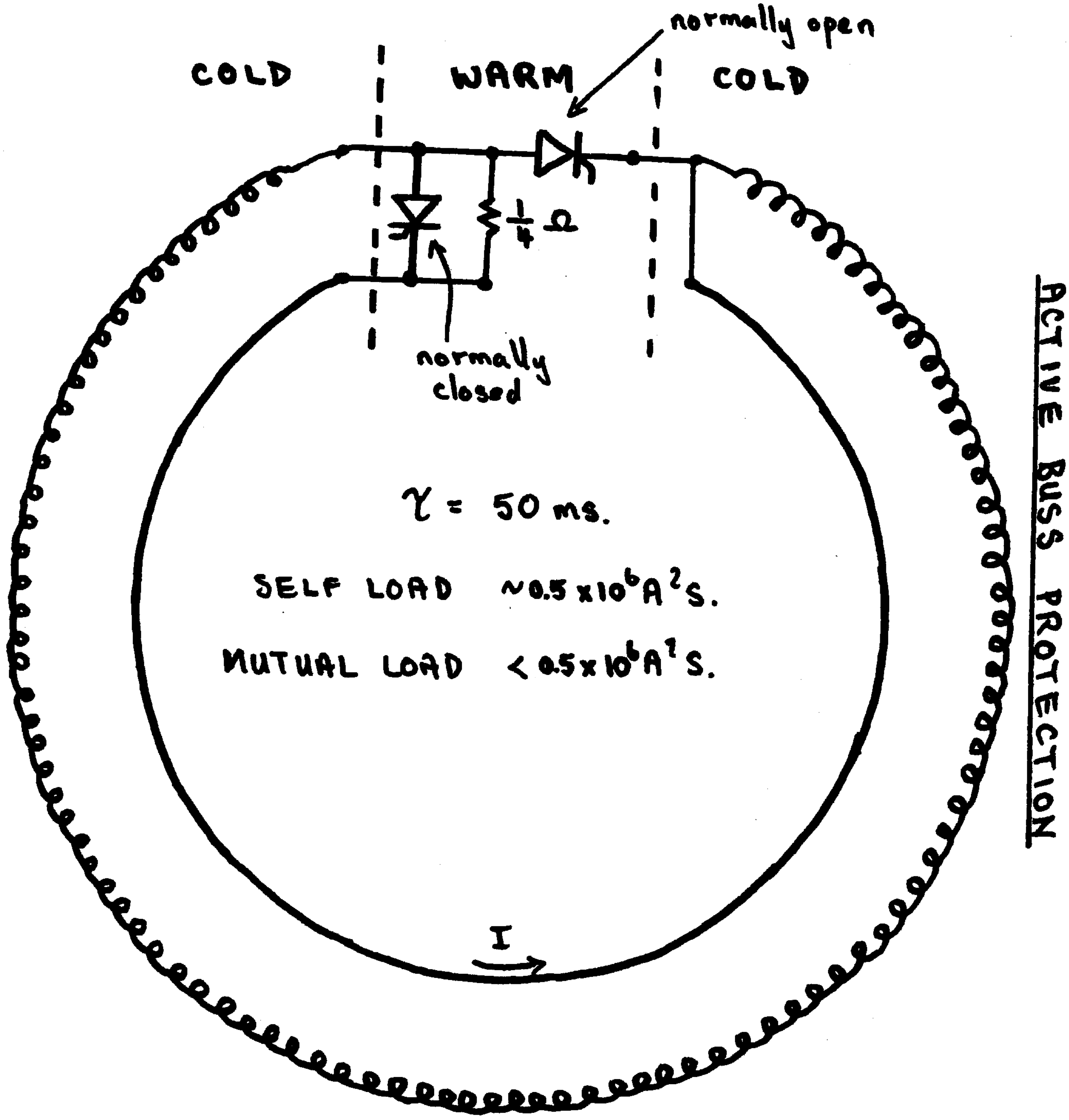

normally open
COLD
WARM
COLD
$\frac{1}{4}\,\Omega$
normally closed
τ = 50 ms.
SELF LOAD ~0.5 x 10^6 A^2 S.
MUTUAL LOAD < 0.5 x 10^6 A^2 S.
I
ACTIVE BUSS PROTECTION

FIGURE 9